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Original Article

Association between the dietary factors and metabolic syndrome with chronic kidney disease in Chinese adults

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Abstract: Objective: The aim of study was to examine the relationship between the dietary nutrition and the prevalence and risk of renal damage in patients with metabolic syndrome. Methods: 260 patients with metabolic syndrome and chronic renal disease meeting criterion were recruited in this cross-sectional study. Metabolic syndrome was defined according to NCEP-ATPIII guidelines. Food-frequency questionnaire was performed to collect the information on dietary nutrition. Anthropometric measurements, including body weight, height and waist circumference were collected. Blood pressure, triglyceride, cholesterol, high density lipoprotein-cholesterol and fasting plasma glucose, renal function and 24-hour urine protein were measured. The correlations between GFR and actual nutrient intakes of participants were examined. Results: The actual intakes of energy, carbohydrates, protein, fat and cholesterol in participate were all significantly higher than recommended nutrient intakes/adequate intakes of Chinese Dietary Reference Intakes. GFR was significantly inversely correlated with energy, protein intake, cholesterol intake, carbohydrates intake, sodium intake, calcium intake and actual protein/energy ratio. Logistic regression analyses showed that actual protein intakes/recommended protein intakes (APIs/RPIs) were significant independent predictors of GFR < 60 ml/min •1.73 m^2. Conclusions: Dietary nutrition is closely correlated with kidney damage in patients with metabolic syndrome. High protein intakes may be one of the risk factors of renal damage.

Keywords: Metabolic syndrome, chronic kidney disease, dietary

Introduction

Chronic kidney disease (CKD) has become a global public health challenge and its prevalence has reached 10-13% of the population worldwide [1]. CKD is a major risk factor for end-stage renal disease (ESRD), cardiovascular disease [2] and is associated with substantial health and economic costs [3]. In china, the overall prevalence of CKD was 10.8%, corresponding to approximately 119.5 million people [4]. Nonetheless, only 10%-15% of Chinese patients with ESRD are able to be treated with renal replacement therapy [4]. CKD frequently progresses and becomes more severe over time, and patients with ESRD have a poorer quality of life and a shorter life expectancy.

CKD is reported associated with multiple physiological and metabolic disturbances, such as hypertension, dyslipidemia and the anorexia-cachexia syndrome which are linked to poor outcomes and increased risk of mortality [5]. Metabolic syndrome is characterized by a clustering of cardiovascular risk factors, such as abdominal obesity, high blood pressure, hyperglycaemia, hypertriglyceridaemia and low high-density lipoprotein cholesterol (HDL-C). Several cross-sectional studies have demonstrated the relationship between the metabolic syndrome and CKD. A cross-sectional study by Hoehner et al. correlated the metabolic syndrome profile and microalbuminuria of American Indians from Wisconsin and Minnesota. They found that individuals with three or more metabolic syndrome traits had a 2.3-fold increased odds of having microalbuminuria compared with a control group without the syndrome [6]. Chen et al. extracted data from the Third National Health and Nutrition Examination Survey database and found a statistical association between metabolic syndrome and microalbuminuria, they also discovered a significant correlation between number of metabolic syndrome factors and GFR < 60 ml/min [7]. Chen et al, reported a strong association between the metabolic syndrome and risk of CKD in Chinese adults, participants with 1, 2, 3 and 4 or 5 components of the metabolic syndrome had a 1.51, 1.50, 2.13 and 2.72-fold increased odds of CKD, respectively, compared with those without any component [7].

Nutritional and metabolic derangements are common in CKD and play a crucial role in affecting clinical outcome in this patient population [8]. Therefore, Dietary assessment is of importance in providing optimal care to individuals with CKD patients, and in particular to dialysis patients. A few epidemiological studies have evaluated the prevalence and consequence of malnutrition in CKD [9, 10], and multiple epidemiologic studies have confirmed the close association between nutritional status and clinical outcomes of CKD. However, the relationship between the dietary nutrition and the prevalence and risk of renal damage in patients with metabolic syndrome has not been studied. To determine whether the dietary nutrition was associated the development of renal damage in metabolic syndromes, we performed a dietary nutrition survey to assess the nutritional status of 260 patients with metabolic syndrome and chronic renal disease.

Patients and methods

Study population

350 patients with metabolic syndrome and chronic renal disease diagnosed and treated at Tianjin people's hospital from October, 2009 to October, 2010 were recruited in this cross-sectional study. Total of 260 patients completed the survey and examination, the overall response rate was 74.3%. Among these patients, 111 were male and 149 were female. The mean age was (55.84 ± 9.80) years. Inclusion Criteria were: patients were diagnosed as metabolic syndrome and chronic renal disease according to the criteria. Exclusion Criteria were: patients who cannot complete the surveys; patients who have anorexia, nausea, vomiting and other gastrointestinal symptoms, and the dietary intake were change; patients who obtain dietary intervention for over 1 month; combination of malignant tumor and other sever illness, such as severe liver disease, hyperthyroidism and heart failure et al. The study was approved by the ethical committee of Tianjin Union Medicine center. Written informed consent was obtained from each participant prior to data collection.

Definition of MS and CKD

MS was defined according to the criteria recommended in the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATPIII) guidelines [11]. The presence of any three of the following five factors is required for a diagnosis of Metabolic Syndrome: waist circumference ≥ 90 cm in men or ≥ 80 cm in women; hypertriglyceridaemia (triglycerides ≥ 1.7 mmol/L); low HDL cholesterol (HDL cholesterol l ≤ 1.0 mmol/L for men and ≤ 1.3 mmol/L for women); elevated blood pressure (systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or current use of antihypertensive drugs); impaired fasting glucose (fasting plasma glucose ≥ 5.6 mmol/L or use of glucose-lowering medicine). CKD was defined as a GFR of < 60 ml/min/1.73 m^2 according to the US National Kidney Foundation guidelines [12]. Glomerular filtration rate (GFR) was estimated from the simplified equation developed using MDRD (Modification of Diet in Renal Disease) data: Estimated GFR = 186.3 × (serum creatinine in mg/88.4)$^{-1.154}$ × age$^{-0.203}$ × (0.742 for women), or proteinuria by a dipstick urine analysis score of 1+ or more.

Data collection

In this study, participants underwent questionnaire interviews and anthropometric measurements by well-trained nurses under a standardized protocol. Food-frequency questionnaire [13] was used to collect the information on dietary nutrition in recent one year and a variety of food, energy and nutrient intake of each participant were calculated to converted into a man-days per standard volume.

During the clinical examination, anthropometric measurements including body weight, height and waist circumference were collected by trained nurses and using standard protocols and technique. Body weight and height were measured twice and in light indoor clothing without shoes. Waist circumference was measured at 1 cm above the navel at minimal respiration. Body mass index (BMI) was calculated as weight (kg) divided by height^2 (m^2). Blood

Table 1. Characteristics of the patients (n = 260)

Characteristics	Mean ± SD
Age (years)	55.84 ± 9.80
Waist circumference (cm)	91.92 ± 8.19
BMI (kg/m^2)	27.20 ± 3.85
Systolic blood pressure (mmHg)	153.75 ± 15.04
Diastolic blood pressure (mmHg)	87.49 ± 9.86
Fasting plasma glucose (mmol/L)	8.42 ± 1.84
TC (mmol/L)	5.77 ± 0.85
TG (mmol/L)	1.78 ± 0.27
HDL-C (mmol/L)	1.33 ± 0.22
Urine protein (g/24 h)	1.78 ± 1.23
CR (μmol/L)	149.13 ± 55.58
GFR （ml/min •1.73 m^2）	52.83 ± 20.15

BMI, body mass index; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesferol; CR, creatinine; GFR, glomerular filtration rate.

pressure was measured thrice with a standard mercury sphygmomanometer. Overnight fasting blood samples were collected for measurement of triglyceride, cholesterol, HDL cholesterol and fasting plasma glucose, renal function and 24-hour urine protein. Plasma glucose was measured using glucose oxidase method, TG was measured using Glycerol phosphate oxidase method, renal function and cholesterol were measured by oxidase method, HDL-C and 24-hour urine protein were measured by colorimetric method.

Dietary nutrition evaluation

A variety of food, energy and nutrient intake of each participant were calculated to convert into man-days per standard volume. Dietary nutrition were evaluated using recommended nutrient intakes/adequate intakes (RNIs/AI) of Chinese Dietary Reference Intakes (DRIs) [14].

Data statistics

The survey data were double-blind entered into Excel database (Microsoft® Excel 2007, Microsoft Corporation, Seattle, USA) and statistical analysis was performed with SPSS 13.0 for Windows (SPSS, Chicago, IL).

Continuous variables were expressed as the mean ± SD and compared using Student's t test. Categorical variables were expressed as a percentage and compared using the χ^2 test. Univariate analysis was performed using linear correlation analysis. Multivariate analysis was performed using multiple linear regression analysis and Logistic regression analysis. Blood pressure, cholesterol and plasma glucose were adjusted for multivariate analysis. All tests were 2-tailed and *P*-value less than 0.05 were considered statistically significant.

Result

The general characteristics of study participants are presented by metabolic syndrome status in **Table 1**. Of the 260 participants included in this study, the mean age was (55.84 ± 9.80) year, 111 (42.7%) were male, and 149 (57.3%) were female. The prevalence of three, four, or five components of the MS patients was 82, 152, 26, respectively, defined by the criteria of NCEP-ATP III. 253 (97.3%) subjects accompanied by urine protein, of these, 195 (75%) were combined with GFR < 60 ml/min/1.73 m^2. According to the classification of CKD stage [15], the prevalence of one, two, three or four stages of the MS patients was 13, 52, 127 and 68, respectively.

We used food-frequency questionnaire to collect the information on dietary nutrition in recent one year and a variety of food, energy and nutrient intakes of each participant were calculated and converted into a man-days per standard volume. As shown in **Table 2**, the actual intakes (ANIs) of energy, carbohydrates, protein, fat and cholesterol were all significantly higher than recommended nutrient intakes/adequate intakes (RNIs/AI) of Chinese Dietary Reference Intakes (DRIs), the ANIs/RNIs ratio was (160.59 ± 47.5)%, (18.68 ± 34.63)%, (194.60 ± 65.73)%, (183.69 ± 82.68)% and (208.5 ± 77.98)%, respectively.

In addition to evaluate the prevalence of dietary nutrition in this study, we next examined the correlations between GFR and other factors including general characteristics and actual nutrient intakes of participants. As shown in **Table 3**, GFR was inversely correlated with several general characteristics such as age, MS component, waist circumference, BMI, systolic blood pressure, diastolic blood pressure, TC, TG, HDL, fasting plasma glucose, urine protein; and actual nutrient intakes, such as energy, protein intake, cholesterol intake, carbohydrates intake, sodium intake, calcium intake and actual protein/energy ratio. Whereas gender and actual carbohydrates/energy ratio

Table 2. Comparison of ANIs with RNIs and energy ratio

	Energy (KJ)	Carbohydrates (g)	Protein (g)	Fat (g)	Cholesterol (mg)	Protein/ energy ratio	Fat/energy ratio	Carbohydrates/ energy ratio
RNIs	1986.92 ± 191.87	322.87 ± 31.18	69.23 ± 4.95 (male 75 g, Female 65 g)	66.23 ± 6.39	300	0.14 ± 0.01	0.25 (0.20-0.30)	0.6 (0.55-0.65)
ANIs	3192.11 ± 1044.93	375.85 ± 119.26	134.95 ± 47.75	127.76 ± 60.38	627.92 ± 231.1	0.17 ± 0.02	0.35 ± 0.08	0.48 ± 0.073
ANIs/RNIs	160.59 ± 47.5	118.68 ± 34.63	194.60 ± 65.73	183.69 ± 82.68	208.5 ± 77.98			
T	-19.399	-7.348	-22.71	-16.846	-22.835	-16.557	-11.301	37.883
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

RNIs, recommended nutrient intakes; ANIs, actual nutrient intakes.

Table 3. Correlations between GFR and variables

Variable	r[a]	*p*-value
Age	-0.289	0.000
Gender[a]	0.150	0.015
MS component	-0.542	0.000
waist circumference	-0.335	0.000
BMI	-0.221	0.036
Systolic blood pressure	-0.471	0.000
Diastolic blood pressure	-0.339	0.000
TC	-0.389	0.000
TG	-0.281	0.000
HDL-C	-0.258	0.000
Fasting plasma glucose	-0.367	0.000
Urine protein	-0.725	0.000
Energy	-0.361	0.000
protein intake	-0.694	0.000
Fat intake	-0.477	0.000
Cholesterol intake	-0.466	0.000
Carbohydrates intake	-0.536	0.000
Sodium intake	-0.350	0.000
Calcium intake	-0.440	0.000
Actual Protein/energy ratio	-0.189	0.002
Actual Fat/energy ratio	-0.089	0.151
Actual carbohydrates /energy ratio	0.157	0.011

[a]Gender is a categorical variable: male is defined as 1 and female as 2. BMI, body mass index; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol.

were positively associated with GFR. Multiple linear regression analyses were conducted to evaluate the association between predictor variables and GFR. Results showed that GFR was best predicted by age, MS component, urine protein and APIs/RPIs (**Table 4**). In addition to examining concurrent predictors of GFR, a primary goal of the current study was to identify independent predictors of GFR. Multivariate logistic regression analyses were conducted including variables that were significant predictors of GFR in linear regression models. The results are shown in **Table 5**. Results were largely consistent with linear regression; gender, age, MS component, waist circumference, urine protein and APIs/RPIs were found to be significant independent predictors of GFR < 60 ml/min 1.73 m^2.

Discussion

The clinical management of MS is difficult because there is no recognized method to prevent or improve the whole syndrome. The prevalence of the metabolic syndrome was reported to be associated with ethnicity, heredity, diet and behavioral factors, and diet played a very important role in the progress of MS [16]. However, the relationship between the dietary nutrition and the prevalence and risk of renal damage in patients with metabolic syndrome remained unclear. In this study, we performed a food-frequency questionnaire to survey the information on dietary nutrition in recent one year and a variety of food, energy and nutrient intakes in patients with MS and CKD, the survey data were calculated and converted into a man-days per standard volume and the relationship between actual nutrient intakes and recommended nutrient intakes was compared. Our results demonstrated that the actual intakes (ANIs) of energy, carbohydrates, protein, fat and cholesterol were all significantly higher than recommended nutrient intakes/adequate intakes (RNIs/AI). Especially, the protein/energy ratio and fat/energy ratio were both higher than RNIs. To our knowledge, the current study is the first study of dietary nutrition in the progress of renal damage in metabolic syndromes.

Previous litterateurs have showed that high-protein diets were not beneficial for CKD patients, the metabolism of protein stores yields a large number of products that are listed as causes of the uremic syndrome. In addition, foods rich in protein will also contain excessive amounts of salt, phosphates, other ions, and fixed acid, so high-protein diets will increase the tendency for hypertension, hyperphosphatemia, and metabolic acidosis [17, 18]. The current study results also identified a negative and significant relationship between the APIs/RPIs and GFR, the higher APIs/RPIs was associated with higher risk of GFR decline (OR = 1.037; 95% CI = 1.002-1.073), suggesting APIs/RPIs was one of the risk factors influencing the kidney damage of MS. Therefore, nutritional therapy requires regular assessment of dietary compliance and protein stores, based on the low protein diet for the purpose of protection of renal function, it is recommended to increase the non-protein dietary to provide the necessary energy [19].

In addition to above factors, we also found other factors were associated with MS kidney damage. First, gender was found to be a signifi-

Table 4. Multivariate regression with CFR as the dependent variable

Variable	β	S.E.	*p*-value	95% CI
Age (years)	-0.337	.090	.000	-0.514~-0.159
MS component	-7.041	1.410	.000	-9.818~-4.264
Urine protein (g/24 h)	-7.911	0.692	.000	-9.275~-6.547
APIs/RPIs*	-.103	.035	.004	-0.173~-0.034

Adjusted R^2 = 0.719. *APIs/RPIs, actual protein intakes/recommended protein intakes.

Table 5. Multivariate logistic regression with CFR as the dependent variable

Explanatory Variable	*p*-value	Odds Ratio	95% CI	
Gender (1)[a]	.002	36.166	3.853	339.467
Age (years)	.007	1.105	1.028	1.188
MS component	.019	10.324	1.457	73.151
Waist circumference	.009	1.163	1.038	1.304
Urine protein (g/24 h)	.000	7.200	2.724	19.030
APIs/RPIs	.037	1.037	1.002	1.073

The GFR no decrease (GFR ≥ 60 ml/min • 1.73 m^2) is defined as 0 and GFR decrease (GFR < 60 ml/min • 1.73 m^2) as 1. [a]Gender is a categorical variable: male is defined as 1 and female as 2.

cant predictor of GFR, female patients had a 36.16-fold increased odds of having GFR decline compared with male patients (95% CI = 3.853-339.467), this may associated with a higher prevalence of insulin resistance in female patients [20, 21]. Second, age was found to be positively correlated with renal damage of MS patients, we found that decreased risk of GRF was 1.105 times more likely to occur for each 1-year increase in age (95% CI = 1.028-1.188). Aging is associated with evolution of insulin resistance, other hormonal alterations, and increases in visceral adipose tissue, all of which are important in the pathogenesis of the MS [22]. In addition, urine protein was positively associated with renal damage, the decreased risk of GRF increased by a factor of 7.2 (95% CI = 2.724-19.030) with 1 g increase in urine protein. Previous studies reported that there was a positive and graded association between the numbers of MS components and the risk of CKD [23, 24], we also obtained similar results that MS components showed obvious negatively association with GFR, participants with 1 component increase had a 10.324-fold increased odds of the decreased risk of GRF (95% CI = 1.457-73.151). Moreover, as primary evaluation indicators of central obesity, waist circumference was also negatively correlated with GFR, patients with thicker waist circumference had a higher risk of GFR decline (OR = 1.163; 95% CI = 1.038-1.304).

However, there were several limitations in our study. First, this study is a cross-sectional design, which makes it difficult to identify the cause of renal damage of MS patients. Second, although GFR is widely used in clinical diagnosis of CKD, and we use the simplified MDRD GFR equation to diagnose CKD in this study, based on GFR equation is difficult to accurately assess the level of CKD, meanwhile we did not use serum creatinine value to estimate kidney function in this study population which might lead to the underestimate and misclassification of the prevalence of CKD. Finally, this was a single-center study and the study population was not large, it will provide a basis for future and larger scale studies on this topic are needed in future.

In conclusion, the findings of the current study demonstrate that not only gender, age, MS components, waist circumference and urinary protein are a risk factor of GFR decline in MS patients with renal impairment, but also dietary nutrition is closely correlated with kidney damage. High protein intakes may be one of the risk factors of renal damage. Therefore, low-protein diets are nutritionally safe and may as a therapeutic measure in CKD patients. Dietary manipulation should be an integral part of the therapy for patients with progressive CKD.

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Disclosure of conflict of interest

None.

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